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Weed Control in Western Irrigation and Drainage Systems

- *Losses Caused by Weeds*
- *Costs and Benefits of Weed Control*

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WEED CONTROL IN WESTERN IRRIGATION AND DRAINAGE SYSTEMS

Losses Caused by Weeds . . Costs and Benefits of Weed Control[1]

by F. L. Timmons[2]

For many years aquatic and bank weeds in irrigation and drainage systems in the Western States have caused serious losses annually. These weeds cause losses in many ways (4).[3] Submersed waterweeds such as pondweeds (Potamogeton spp.) reduce the flow in channels, causing higher water levels, breakage in canal banks, increased seepage into adjoining croplands, greater losses of water by evaporation and inadequate delivery of irrigation water to farms or inadequate drainage of water from cropland (fig. 1). In addition, decreased velocity of flow causes increased sedimentation; this reduces capacity and makes more frequent mechanical cleaning necessary. Also, algae and fragments of other submersed aquatic weeds clog sprinklers, pumps, screens, valves, and create problems at pumping plants in irrigation and drainage systems. Emergent aquatic weeds such as cattails (Typha spp.) and bank weeds, and phreatophytes like willows (Salix spp.) and salt cedar (Tamarix pentandra) transpire tremendous quantities of water from canals and reservoirs into the dry air (figs. 2, 3, and 4). Weeds prevent proper inspection and maintenance of irrigation and drain canals and serve as sources of seed for infesting nearby fields. Frequently, aquatic weeds and bank weeds are a serious problem in the same channel (fig. 5).

A survey conducted in 1948 by the Bureau of Reclamation of the U.S. Department of the Interior (1) showed that nearly 150,000 acre-feet of water was lost each year in the Bureau's 14,075 miles of canals and laterals because of weeds. By assigning a productive value of $20 per acre-foot to this lost water and adding the cost for ditchbank repairs and damage to flooded crops attributed to weeds, the loss in irrigation systems built by the Bureau of Reclamation was estimated at nearly $3 million annually. When these losses were projected to all irrigation systems in the 17 Western States, by using the 1940 Census figures of 120,386 of unlined canals, an estimate of $25-1/2 million loss annually because of weeds was obtained.

During the next 10 years considerable progress was made in developing more effective and economical chemical methods of control (2). In 1957, a comprehensive survey was planned to obtain up-to-date information on the weed problem in irrigation and drainage systems of the West. The objectives of the survey were

---

[1]Survey study conducted cooperatively by the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the Bureau of Reclamation, U. S. Department of the Interior.

[2]Research Agronomist, Crops Research Division, ARS. Located at College of Agriculture, University of Wyoming, Laramie. Valuable assistance was given by many officials of Bureau of Reclamation offices in developing and distributing the questionnaire and in interpreting the summary data.

[3]Numbers in parentheses refer to Literature Cited, at end of this report.

Figure 1A.--An irrigation canal with a heavy growth of pondweed, anacharis, and algae before treatment.

Figure 1B.--Eight days after treatment with aromatic solvent.

Courtesy of Bureau of Reclamation Region 4, Salt Lake City, Utah.

Figure 2.--A drain canal infested with cattail. Courtesy of Bureau of Reclamation Region 2, Sacramento, Calif.

Figure 3.--An irrigation lateral heavily infested with Johnson grass. In periods of water shortage, when water is removed from the ditch 2 or 3 weeks, Johnson grass will infest the bottom of the ditch, making the deliverance of water impossible. Courtesy of Bureau of Reclamation Region 5, Amarillo, Tex.

Figure 4.--A heavy growth of cottonwood, willows, and miscellaneous annual and perennial herbaceous weeds along a small irrigation lateral. Courtesy of Bureau of Reclamation Region 6, Billings, Mont.

Figure 5.--An irrigation drain canal with cattail in the channel and whitetop *(Lepidium draba)* on the banks. Courtesy of Bureau of Reclamation Region 1, Boise, Idaho.

as follows: 1, To determine the extent of infestation and of losses caused by each of the important types of aquatic and bank weeds; 2, to determine the extent of use and cost of weed control practices on aquatic and bank weeds; and 3, to obtain a reliable estimate of the benefits from weed control in the form of losses prevented.

SURVEY METHODS

A comprehensive questionnaire was prepared and copies submitted to the Bureau of Reclamation regional offices, the Commissioner's office in Washington, D.C., and the Assistant Commissioner and Chief Engineer's office in Denver, Colo., for suggestions. From these suggestions a final draft of the questionnaire was developed which was believed to be well adapted for obtaining the desired information.

Early in 1958 copies of the questionnaire[4] were distributed to more than 200 different irrigation districts and irrigation companies throughout the 17 Western States. The questionnaires were distributed from the seven Bureau of Reclamation regional offices and the Agricultural Research Service Weed Investigations office at Laramie, Wyo., with a request that they be filled out for the calendar year 1957 on the basis, insofar as possible, of cost and survey records, but where complete records were not available that carefully considered estimates be supplied of weed infestations and monetary losses and benefits from weed control.

A total of 47 reports, 4 to 11 at each of the 7 Bureau of Reclamation regions, were sufficiently complete to be included in summaries. Fifteen of the reports were received from projects operated by the Bureau of Reclamation and 32 from private companies or organizations. A list of Bureau of Reclamation regional offices cooperating in the survey, and of the irrigation districts or projects and water-users organizations submitting reports which were summarized in this general report, is presented below:

Bureau of Reclamation Region 1, Boise, Idaho

- Aberdeen-Springfield Canal Co., Aberdeen, Idaho
- Columbia Basin Project, U.S. Bureau of Reclamation, Ephrata, Wash.
- Kittitas Reclamation District, Ellensburg, Wash.
- North Side Pumping Division, Minidoka Project, U.S. Bureau of Reclamation, Rupert, Idaho
- Ochoco Irrigation District, Prineville, Oreg.
- Roza Division, Yakima Project, U.S. Bureau of Reclamation, Sunnyside, Wash.
- Sunnyside Valley Irrigation District, Sunnyside, Wash.
- Vale Oregon Irrigation District, Vale, Oreg.

Bureau of Reclamation Region 2, Sacramento, California

- Central California Irrigation District, U.S. Bureau of Reclamation, Los Banos, Calif.
- Fresno Irrigation District, Fresno, Calif.
- Klamath Irrigation District, U.S. Bureau of Reclamation, Klamath Falls, Oreg.
- Lower Tule River Irrigation District, Porterville, Calif.

[4]Copies of the questionnaire are available from the author.

Bureau of Reclamation Region 2, Sacramento, California -- Continued

Madera Irrigation District, Madera, Calif.
Panoche Water District, South Dos Palos, Calif.

Bureau of Reclamation Region 3, Boulder City, Nevada

Coachella Valley County Water District, Coachella, Calif.
Colorado River Indian Agency, Parker, Ariz.
Imperial Valley Irrigation District, Imperial, Calif.
Salt River Valley Water Users Assn., Phoenix, Ariz.

Bureau of Reclamation Region 4, Salt Lake City, Utah

Fruitgrowers Dam Project, Orchard City Irrigation District, Austin, Colo.
Grand Valley Project, Grand Valley Water Users Assn., Grand Junction, Colo.
Hyrum Project, South Cache Water Users Assn., Wellsville, Utah
Newton Project, Newton Water Users Assn., Newton, Utah
Paonia Project, The Fire Mountain Canal & Reservoir Co., Hotchkiss, Colo.
Pine River Project, Pine River Irrigation District, Durango, Colo.
Preston Bench Project, Preston, Riverdale & Mink Creek Canal Co., Preston, Idaho
Provo River Project, Provo River Water Users Assn., Provo, Utah
Sanpete Project, Horseshoe Irrigation Co., Spring City, Utah
Strawberry Valley, Strawberry Water Users Assn., Payson, Utah
Uncompahgre Project, Uncompahgre Valley Water Users Assn., Montrose, Colo.

Bureau of Reclamation Region 5, Amarillo, Texas

Carlsbad Project, Carlsbad Irrigation District, Carlsbad, N. Mex.
Middle Rio Grande Project, U.S. Bureau of Reclamation, Albuquerque, N. Mex.
Rio Grande Project, U.S. Bureau of Reclamation, El Paso, Tex.
Tucumcari Project, Arch Hurley Conservancy District, Tucumcari, N. Mex.

Bureau of Reclamation Region 6, Billings, Montana

Angostura Project, U.S. Bureau of Reclamation, Oral, S. Dak.
Buffalo Rapids Project, Terry, Mont.
Crow Creek Project, U.S. Bureau of Reclamation, Great Falls, Mont.
Fort Clark Project, U.S. Bureau of Reclamation, Bismarck, N. Dak.
Midvale Irrigation District, Pavillion, Wyo.
Milk River Project, U.S. Bureau of Reclamation, Malta, Mont.
Riverton Third Division, U.S. Bureau of Reclamation, Riverton, Wyo.
Sun River Greenfields Irrigation District, Fairfield, Mont.

Bureau of Reclamation Region 7, Denver, Colorado

Casper-Alcova Irrigation District, Casper, Wyo.
Courthouse Rock Irrigation District, Bridgeport, Nebr.
Goshen Irrigation District, Torrington, Wyo.
Lake Canal Company, Fort Collins, Colo.
New Brantner Extension Ditch Company, Brighton, Colo.
Winters Creek Canal Company, Scottsbluff, Nebr.

The geographical area included within each Bureau of Reclamation region is shown in figure 6.

The reports covered 14.8 percent of the total mileage of canals and ditches in the 17 Western States as reported for 1950 by the Bureau of the Census (5). From that census report[5] it was determined that the percentage of canals and ditches included in the study of the seven regions ranged from 4.2 to 25.7.

The Reclamation offices reported that the individual reports received constituted a representative sample of all of the irrigation districts and canals in each region. Therefore, the survey data on miles of waterway and acres of ditchbanks infested were extrapolated into estimates of total weed infestation, water and other losses caused by weeds, costs of weed control, and losses prevented by weed control in each region and in the 17 Western States. The factors for multiplying the survey data were determined by dividing the number of miles of canals and ditches reported in the 1950 census[5] by the number of miles of canals reported in the survey. As may be seen in Appendix table 7, the factors ranged from 3.89 to 24.04 in the several regions and averaged 6.76 for the 17 Western States as a whole (the 7 regions).

Data from all reports from the 47 irrigation districts and canal companies were tabulated, summarized, and interpreted in the Agricultural Research Service Weed Investigations office at Laramie, Wyo. Copies of the regional and overall tabular summaries and discussion of results were returned to the Bureau of Reclamation regional and Commissioner's offices for review and suggestions.

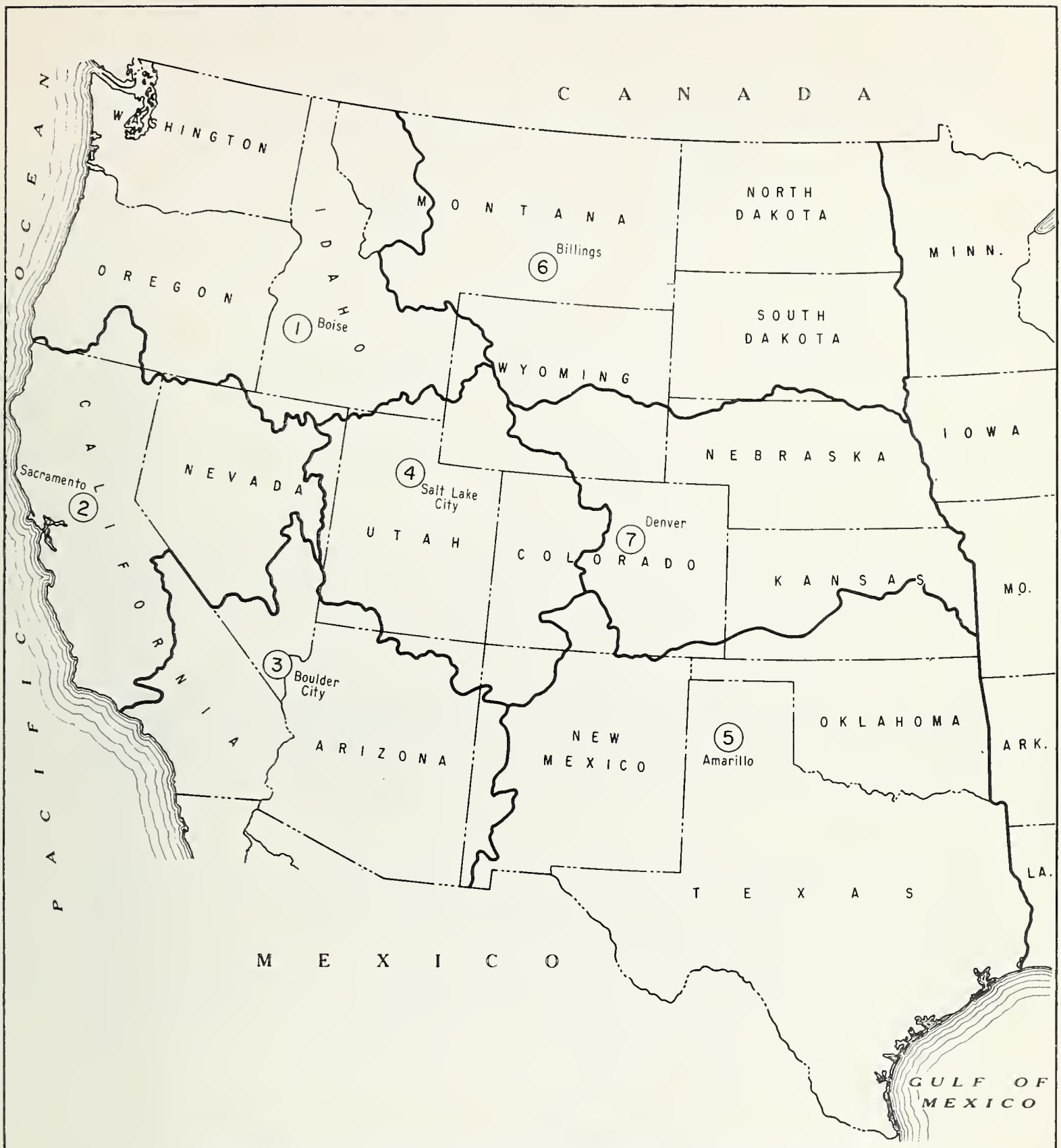
RESULTS

The data from the 47 individual reports from all 7 regions are summarized by region in the comprehensive Appendix table 7. An extrapolation of these data into estimates for all irrigation districts and canal companies in the 17 Western States is summarized by region in Appendix table 8. The data are summarized by kind of weed, type of channel, and other categories in tables 1 to 6. In tables 2 and 3 the Bureau of Reclamation regions in the 17 Western States are listed in the following geographical order: In the north, from west to east through Regions 1 and 6; in the central part, from east to west through Regions 7, 4, and 2; and in the south, from east to west through Regions 3 and 5.

Aquatic Weed Infestations in Channels

Table 1 shows the percent infestation of the three most important kinds of aquatic weeds in three different types of channels. Rooted submersed waterweeds, mostly pondweeds (fig. 1), were reported to be a problem in 33 percent of the mileage of canals, laterals, and drains as an average of all 47 reports, the infestation being slightly greater in laterals than in canals or drains. Algae was considered a problem in 25 percent of the canals, 11 percent of the laterals, and 18 percent of the drains. Emergent species, chiefly cattails (fig. 2), were a serious problem in the drains with slower moving water, considerably less important in laterals, and of

[5] 1950 census data used for all regions except Region 3, for which more recent survey data were supplied (see footnote 3 of Appendix table 7).



BUREAU OF RECLAMATION REGIONAL BOUNDARIES AND HEADQUARTERS

(CONSTRUCTION WORK IS GENERALLY LIMITED TO PROJECTS IN THE SEVENTEEN WESTERN STATES AND ALASKA)

X-D-4086

FIGURE 6

Table 1.--Percent infestation by aquatic weeds in western irrigation systems, 1957

Type of channel	Average capacity	Infestation by--			
		Algae	Submersed	Emergent	Total
	Cu.ft./sec.	Percent	Percent	Percent	Percent
Canal	589	25	28	6	59
Lateral	41	11	36	16	63
Drain	21	18	31	25	74
Average[1]	-	15.5	33.1	16.5	65.1

[1]Averages weighted according to the number of miles of infested channel in each type.

little importance in the large canals. It is interesting to note than 65 percent of the mileage of all channels was infested with aquatic weeds, the percentages being 59, 63, and 74, respectively, for canals, laterals, and drains.

The extent to which algae and pondweeds were both present in the same channels but reported separately is not known. If this was a common occurrence, the overlapping might mean that the actual mileage of channels infested by aquatic weeds was somewhat less than 65 percent of the total.

As is shown in table 2, the infestations of the different aquatic weeds varied considerably from region to region. Algae was most important in the Pacific Coast Regions 1 and 2 and least important in the southern Region 5. Pondweeds and other submersed aquatics were of little importance in Region 5 but were important in all other regions, especially in Regions 3, 7, and 1. Region 2 had the most serious infestation of cattails and other emergent aquatics, and these weeds were an important problem in all regions except perhaps in Regions 1 and 3. On the whole, Region 5 (New Mexico, Texas, and Oklahoma) was the least troubled with aquatic weeds.

Floating weeds, mostly water hyacinth and water lettuce, were a minor local problem in Regions 3, 5, 2, and 1, where they occurred mostly in drain canals (Appendix table 7). None were reported in Regions 4, 6, or 7. The infestations of floating weeds were not important enough to be included in summary tables 1 and 2 nor to be extrapolated into estimates for the 17 Western States in table 4 or in Appendix table 8.

Table 2.--Percent infestation by 3 kinds of aquatic weeds in western irrigation systems, 1957

Kind of weed	Infestation in Bureau of Reclamation Region --							Average[1]
	1	6	7	4	2	3	5	
	- - Percent - -							
Algae	21	17	13	12	24	8	2	15.5
Submersed (pondweeds, etc.)	37	30	52	18	15	61	6	33.1
Emergent (cattails, etc.) . .	5	16	22	16	41	8	11	16.5
Total	63	63	87	46	80	77	19	65.1

[1]Averages weighted according to total number of miles in each region.

Weed Infestations on Ditchbanks

Table 3 shows the percent infestation of the four important kinds of ditchbank weeds. Broadleaved weeds were most prevalent in Region 4 and least prevalent in Regions 2, 3, and 5, averaging 7 percent of the ditchbanks in all regions. Perennial grasses were important in all regions except northern Regions 1 and 6 (fig. 3). Woody plants were a serious problem in southern Regions 3 and 5, but they were scarce in coastal Regions 1 and 2 and only moderately important in Regions 4, 6, and 7 (fig. 4). Annual weeds were prevalent in all regions except Region 3, where they probably were prevented by low rainfall or crowded out by Johnson grass and woody plants. The acreage of all ditchbanks covered in the 47 reports averaged 74 percent infested by weeds. The percent infestation ranged from only 41 in northern Region 6 to 100 in southern Region 5.

Table 3.--Percent infestation by 4 kinds of ditchbank weeds in western irrigation systems, 1957

Kind of weed	Infestation in Bureau of Reclamation Region --							Average[1]
	1	6	7	4	2	3	5	
	-- Percent --							
Broadleaved perennials . . .	9	10	11	21	2	4	3	7
Perennial grasses.	1	0.3	42	24	18	32	10	16
Woody plants	1	10	7	17	1	47	30	21
Annuals	47	21	33	35	41	6	57	30
Total	58	41	93	97	62	89	100	74

[1]Averages weighted according to the total number of acres of infested ditchbanks in each region.

Table 4 expresses the percentage figures of the two previous tables in total miles of channel and total acres of ditchbank infested by the different kinds of weeds. These data should be useful to manufacturers and distributors who are interested in estimating the total potential usage of or market for new improved herbicides or other control methods. For that purpose the extrapolated figures for all irrigation systems in the 17 Western States are of most interest. Of the 144,381 miles of canals and ditches reported in the 1950 census,[6] about 20,000 miles were infested by algae, about 47,000 miles by submersed aquatic weeds, and nearly 23,000 miles by emergent aquatic weeds. Of the 527,683 acres of ditchbanks, approximately 42,000 acres were infested by broadleaved perennial weeds, 87,000 acres by perennial grasses, 99,000 acres by woody plants, and 166,000 acres by annual weeds.

Table 4.--Miles of irrigation channels and acres of ditchbanks infested with weeds, 1957

Kind of weed	Reported by 47 districts	Extrapolated totals in 17 Western States
	Miles	Miles
(All channels, total length within respective areas)	(21,400)	(144,381)[1]
A. Aquatic weeds:		
Algae	3,318	20,462
Submersed	7,079	47,380
Emergent	3,527	22,926
Subtotal	13,924	90,768
	Acres	Acres
(All ditchbanks, total acreage within respective areas)	(88,868)	(527,683)
B. Bank weeds:		
Broadleaved perennials	6,002	42,236
Perennial grasses	14,394	87,356
Woody plants	18,197	98,954
Annuals	26,239	166,474
Subtotal	64,832	395,020

[1]Figure from Bureau of the Census, U. S. Department of Commerce (1950 Census), with adjustment for Region 3, for which more recent survey data were supplied (see footnote 3 in Appendix table 7).

[6]See table footnote above.

Water Losses From Weeds

The total losses from weeds in western irrigation systems in 1957, shown in much more detail in Appendix tables 7 and 8, are summarized in table 5. The 47 districts reported a total estimated water loss of 328,943 acre-feet from transpiration, increased evaporation, and overflows because of weeds. Water losses from aquatic weeds were more than three times those caused by ditchbank weeds. The total estimated water loss of 1,966,068 acre-feet in the 17 Western States would have been enough to irrigate 330,000 to 780,000 acres of cropland depending upon the length of growing season, evaporation losses, and other factors.

The cost of water lost because of weeds represents the actual cost to water users. This average cost varied in different regions from $1.09 to $3.32 per acre-foot. The costs among the 47 reporting districts ranged from $0.40 to $10 per acre-foot. Using these rates per acre-foot, the total cost of water lost in the 47 reporting districts was $678,966 and the total cost in the 17 Western States was $3,626,742.

Table 5.--Losses from weeds in western irrigation systems, 1957

Item	Reported by 7 regions (47 districts)	Extrapolated totals in 17 Western States
	Acre-feet	Acre-feet
Water lost:		
Aquatic weeds	252,861	1,375,746
Ditchbank weeds	76,082	590,322
Total	328,943	1,966,068
Cost of water lost:		
Aquatic weeds	$547,169	$2,667,502
Ditchbank weeds	131,797	959,240
Total	$678,966	$3,626,742
Cost of other damage:		
Aquatic weeds	$178,250	$1,304,488
Ditchbank weeds	136,000	807,934
Total	$314,250	$2,112,422
Total losses:		
Aquatic weeds	$725,419	$3,971,990
Ditchbank weeds	267,797	1,767,174
Total	$993,216	$5,739,164

Other Losses From Weeds

The costs not included in water losses that are caused by weeds, such as damage to canals, structures, crops, and farmland were more than $300,000 on the 47 reporting projects and over an estimated $2 million in the 17 Western States (table 5). This brought the total cost of weed losses for the reporting projects up to $993,216 and for all irrigation systems in the 17 Western States up to $5,739,164.

The data on acreages of weeds in flood plains and reservoirs and losses from weeds in these situations (shown in Appendix table 7) were incomplete, especially in Regions 2, 3, and 5. Several districts reporting from these regions did not indicate any weeds in flood plains and reservoirs. However, extensive acreages of phreatophytes are known to exist in these districts. Therefore, the data on flood plains and reservoirs were not extrapolated into estimates for all 17 Western States and were not included in tables 1 through 6.

Costs of Weed Control

The 47 reporting districts spent $1,426,705 for weed control in 1957 (table 6). The total cost of weed control in the 17 Western States was $8,113,297. The expenditure for control of ditchbank weeds was more than three times the expenditure for aquatic weed control. Only 54 percent of the infested mileage of aquatic weeds was treated, but 80 percent of the infested acreage of ditchbanks was treated. When

Table 6.--Reported and extrapolated costs of weed control in western irrigation systems, 1957

Report or estimation	Aquatic weeds	Ditchbank weeds	Total
	Miles	Acres	
A. Report from 7 regions (47 districts):			
Infestation	13,924	64,832	-
Treatment	7,449	51,791	-
	Dollars	Dollars	Dollars
Cost of treatment	315,555	1,111,150	1,426,705
Estimated losses prevented	765,829	2,034,176	2,800,005
B. Estimation pertaining to 17 Western States:			
Cost of treatment	1,592,130	6,521,167	8,113,297
Losses prevented	3,922,608	11,937,418	15,860,026
Net saving	-	-	7,746,729

it is recalled that the estimated losses from aquatic weeds were nearly three times the losses from ditchbank weeds, it becomes clear that improved methods of controlling aquatic weeds have not been adopted nearly so generally as have improved methods of controlling ditchbank weeds. For example, the use of aromatic solvents for control of pondweeds has been practiced extensively only in Regions 1 and 3, even though pondweeds are a serious problem in most of the other regions. The much higher cost of aromatic solvents in the smaller quantities used in most of the other regions may be an important factor in this difference. The general lag in adoption of control methods for aquatic weeds indicates a need for further improvement in methods of controlling aquatic plants, especially rooted submersed waterweeds in larger canals.

As is shown in Appendix table 7, the average cost per mile of treating aquatic weeds ranged from $11.08 in Region 6 to $121.42 in Region 7, averaging $42.36 for all regions. The cost per mile also varied greatly for different species of aquatic weeds and different methods of control. The methods used included drying, handcutting, and cleaning, and chaining, draglining, and treating with chemicals (shown in figs. 7, 8, and 9). The low average cost of control in Region 6 may have been the result of more extensive use of the inexpensive drying method.

The cost of ditchbank weed control averaged $21.45 per acre for all regions, ranging from $6.26 in Region 1 to $55.62 in Region 3 (Appendix table 7). In general, the cost of control per acre was relatively low in regions where extensive use can be made of 2,4-D; but in regions where 2,4-D can be used only sparingly because of cotton or other sensitive crops and where more expensive chemicals or methods must be used, the cost of control was much higher. Methods of controlling ditchbank weeds included hand cutting, mowing, burning, and spraying with many different kinds of equipment (figs. 10-13). Benefits from control treatments are shown in figs. 1-B, 14, and 15.

The total amount of weed losses prevented by the control programs in the 47 reporting districts was $2,800,005, a ratio to costs of approximately 2:1 (table 6). The ratio of estimated saving from aquatic weed control to cost was 2.4:1, while the ratio for ditchbank weed control was 1.8:1. The extrapolated figures for all irrigation systems in the 17 Western States place the total cost of weed control at $8,113,297 and the total estimated weed losses prevented by weed control at $15,860,026. This was a net saving of $7,746,729 due to weed control. This annual net saving of approximately $7-3/4 million is a sizeable return on the Nation's investment in research, extension, and other efforts directed toward the development and use of improved methods of controlling weeds in the irrigation and drainage systems of the West.

Total Losses and Costs Caused by Weeds in the 17 Western States in 1957

When we add the losses from weeds, $5,739,164 shown in table 5, to the cost of weed control, $8,113,297 shown in table 6, we get a total loss from weeds of $13,852,461 in the 17 Western States for 1957. This is the actual cost to the water user of water lost and other direct losses caused by weeds and of control of weeds in irrigation systems. Presumably all the estimated losses of $15,860,000 which

Figure 7.--Chaining an irrigation canal to remove pondweed, cattails, and other submersed and emergent weeds. The use of aromatic solvents and other chemicals is replacing this type of mechanical treatment in small and medium size channels. Courtesy of Bureau of Reclamation Region 1, Boise, Idaho.

Figure 8.--Removing cattail and other weeds from a drainage ditch at the cost of about $400 per mile. Chemical control of cattail in canals and ditches has been accomplished with a small fraction of that cost. Courtesy of Bureau of Reclamation Region 6, Billings, Mont.

Figure 9.--Aromatic solvent, used for killing submersed weeds in irrigation canals, forms a milky emulsion as it mixes with the water. Courtesy of Bureau of Reclamation Region 1, Boise, Idaho.

Figure 10.--Mowing of bank weeds and emergent aquatic weeds gives temporary control and reduction of transpiration losses. Frequently, enough of the mowed vegetation falls in the water to cause clogging of structures downstream. Courtesy of Bureau of Reclamation Region 2, Sacramento, Calif.

Figure 11.--Burning woody growth olong a large canal with a truck-mounted counterbalonced boom. Courtesy of Bureau of Reclamotion Region 3, Boulder City, Nev.

Figure 12.--Spraying Johnson grass along a lateral in Arizono with hoses and hand guns from a slowly moving tank truck. Courtesy of Bureau of Reclamation Region 3, Boulder City, Nev.

Figure 13.--Spraying miscelloneous annual ond perenniol bank weeds olong a concrete-lined irrigotion conal with a 3-section truck-mounted boom. Courtesy of Bureou of Reclamotion Region 2, Sacromento, Colif.

Figure 14.--Spraying bank weeds olong a canal in Washington with a helicopter. Courtesy of Bureau of Reclamation Region 1, Boise, Idaho.

Figure 15.--This irrigation lateral in New Mexico was formerly os heovily infested with Johnson grass os the loteral shown in Figure 3 before two complete seosons of frequent burning resulted in the cleon ditchbank. Courtesy of Bureou of Reclamation Region 5, Amorillo, Tex.

were prevented by weed control in 1957 would have been included in losses caused by weeds had it not been for the weed control practices in use. Probably the extensive use of more effective and less expensive methods of weed control in 1957 than were known in 1947 was an important factor in holding weed losses and costs relatively low in 1957.

DISCUSSION

These figures on weed losses in 1957 cannot be compared directly with the Bureau of Reclamation's estimated loss of $25-1/2 million caused by weeds in 1947, because of the difference in the basis of evaluating losses in the two surveys. If the average productive value of $20 per acre-foot of irrigation water used as the basis of the survey of weed losses in 1947 had been applied to the estimated 1,966,068 acre-feet of water lost in 1957 because of weeds, the total value of the water lost would have been estimated at $39,321,360 instead of $3,626,742, the actual cost to the water user. Actually the total loss to the water users and the economy of the Nation in 1957 may have been much closer to the former figure than to the latter.

A partial answer to the above question is afforded by a study of some of the 1957 data based upon net productive values of irrigation water submitted by Bureau of Reclamation Regions 1, 2, 3, and 5 in terms of net profit or labor income. These values ranged from $8.33 to $31.33 per acre-foot (Appendix table 7). In these four regions, where water shortages frequently are critical and/or additional irrigable land is available so that all water lost because of weeds could have been used productively, the total net productive value of water lost in the 22 irrigation districts and companies reporting would have been $5,346,936. Using the extrapolation factors applicable to each region, the total net productive value of water lost because of weeds in all the irrigation districts and companies in the four regions would be estimated at $25,775,538.

Even when actual cost figures of water lost in 1957 are used, the total of all losses from weeds and the costs of weed control, amounting to $13,852,461, and the estimated net saving due to weed control amounting to $7,746,729, are impressive figures. It is suggested that similar surveys of weed losses, costs of weed control, and benefits of weed control on irrigation systems should be conducted periodically in the future, e.g., every 10 years, to measure changes in weed infestations and progress in weed control.

It is believed that on the whole the estimates of losses caused by weeds and losses prevented by weed control may have been less than the actual losses and savings, especially those extrapolated from the survey data into estimates for the 17 Western States. Some of the reporting districts failed to answer some of the questions on the questionnaire about losses incurred or prevented. A number of districts answered such questions with a question mark (?), indicating a lack of actual records and a reluctance to make an estimate. Wherever questions about losses caused by weeds or losses prevented by weed control were not answered, it was assumed, for summary purposes, that there were no losses incurred or prevented even though it was apparent in a number of cases that such losses had occurred but had not been estimated.

It is probable that the total mileage of channels was somewhat greater in 1957 than it was in 1950 in most of the regions, so that the percentage of the total mileage covered by the 47 reports was actually less than 4 to 26 (average 14.8) as calculated on the basis of data from the 1950 Census. Thus, the factors for multiplying totals from the 47 reporting districts to obtain totals for the 7 regions[7] and the 17 Western States probably were somewhat too low.

Nevertheless, the estimate of the total cost of weed control in 1957 in the 17 Western States may have been somewhat higher than the actual total cost. It is possible that the 47 reporting districts were more progressive than most of the districts and may have made more extensive use of weed control practices than average. To the extent, therefore, that the nonreporting districts and companies made less extensive use of weed control practices, their losses caused by weeds were no doubt greater than those of the reporting districts.

It should be pointed out again that the extrapolated estimates of all losses from weeds and costs of weed control for the different regions and the 17 Western States do not include those involving phreatophytes except as they were classified as woody plants occurring on ditchbanks. The losses from transpiration, flood damage, and sedimentation caused by the extensive acreages of phreatophytes around reservoirs, along streams, and on river flood plains were not covered by the survey, nor were the costs of phreatophyte control in these situations. The losses from phreatophytes and possible savings from control of phreatophytes are discussed in another publication (3).

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[7]See footnote 5.

APPENDIX

Table 7.--Summary of data on weed infestations, losses from weeds, and costs of weed control on western irrigation and drainage systems, 1957

ITEM	BUREAU OF RECLAMATION REGIONS							TOTALS	AVERAGES[1]
	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7		
No. of districts or companies reporting	8	6	4	11	4	8	6		
1. General information - mileage of waterways, acreage of ditchbanks, weed infestation									
a. Total miles of waterways									
(1) Canals (miles)	749.0	1,343.5	376.7	530.9	326.2	434.5	199.0	3,960	
Capacity, av. cfs	1,264.3	328.0	1,080.0	127.4	403.1	485.0	651.0		589.2
Weed infestation:									
(a) Algae miles	297.8	417.7	88.4	100.0	10.0	74.1	9.6	997	
Percent	39.8	31.0	23.5	18.8	3.1	17.0	4.8		25.2
(b) Pondweeds miles	227.5	400.2	185.2	70.6	30.0	87.0	94.0	1,095	
Percent	30.4	29.8	49.4	13.3	9.2	20.2	47.2		27.6
(c) Floating species miles	None	15.8	None	0	None	None	None	16	
Percent	0	1.2	0	0	0	0	0		0.4
(d) Emergent species, cattail, etc. miles	13.8	120.2	29.4	41.5	11.0	11.5	None	227	
Percent	1.8	8.9	7.7	7.8	3.4	2.7	0		5.7
(2) Laterals (miles)	3,451.0	2,851.5	2,413.6	949.5	1,002.2	1,276.2	456.0	12,400	
Capacity, av. cfs	20.1	15.2	131.0	17.0	31.9	13.4	19.8		40.6
Weed infestation:									
(a) Algae miles	488.6	445.1	170.8	44.5	24.0	172.0	60.0	1,405	
Percent	14.1	15.6	7.1	4.7	2.3	13.5	13.2		11.3
(b) Pondweeds miles	1,603.8	203.2	1,811.5	137.4	77.1	374.3	201.5	4,412	
Percent	46.5	7.1	75.1	14.5	.7.7	29.3	44.2		35.6
(c) Floating species miles	53.9	16.8	0	0	None	None	None	70	
Percent	1.5	0.6	0	0	0	0	0		0.6
(d) Emergent species, cattail, etc. miles	89.3	1,650.2	44.0	91.9	11.5	97.8	33.9	2,019	
Percent	2.6	57.9	1.8	9.7	1.1	7.8	7.4		16.3
(3) Drains (miles)	1,001.0	230.0	1,864.2	324.4	628.5	767.0	225.0	5,040	
Capacity, av. cfs	16.8	11.3	36.5	2.4	16.9	6.3	1.8		20.7
Weed infestation:									
(a) Algae miles	306.5	203.0	122.0	65.6	10.7	168.2	40.0	916	
Percent	30.6	88.3	6.5	20.2	1.7	21.9	17.8		18.2
(b) Pondweeds miles	98.6	60.0	844.2	112.0	7.5	289.8	160.0	1,572	
Percent	9.8	26.1	45.3	34.5	1.2	37.8	71.1		31.2
(c) Floating species miles	5.0	3.5	122.4	0	40.0	None	None	168	
Percent	0.5	1.5	6.6	0	6.4	0	0		3.4
(d) Emergent species, cattail, etc. miles	142.0	51.5	314.0	151.0	189.8	276.2	156.3	1,281	
Percent	14.2	22.4	16.8	46.5	30.2	35.9	69.2		25.4

Table 7 (Continued)

ITEM	BUREAU OF RECLAMATION REGIONS							TOTALS	AVERAGES[1]
	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7		
b. Total area (acreage) of ditchbanks	27,463	11,216	30,924	4,116	5,462	8,001	1,686	88,868	
(1) Area infested with:									
(a) Broadleaved perennials ..... acres	2,585	274	1,130	844	175	807	187	6,002	
Percent	9.4	2.4	3.7	20.5	3.2	10.1	11.1		6.8
(b) Perennial grasses ..... acres	270	2,013	9,851	988	542	20	710	14,394	
Percent	1.0	17.9	32.1	24.0	9.9	0.3	42.1		16.2
(c) Woody plants ..... acres	300	103	14,571	716	1,615	778	114	18,197	
Percent	1.1	0.9	47.4	17.4	29.6	9.7	6.7		20.5
(d) Annual weeds ..... acres	12,950	4,613	1,770	1,430	3,140	1,682	654	26,239	
Percent	47.2	41.1	5.8	34.7	57.5	21.0	32.9		29.5
2. Losses from weeds - water losses, damage to canals and crops									
a. Aquatic weeds									
(1) Volume of water lost ..... A.-ft	86,531	83,200	43,300	17,470	2,300	19,300	760	252,861	
Value of water lost ..... $ Cost	106,084	287,600	99,802	22,572	6,900	23,125	1,086	547,169	
(2) Damage to canals, structures, and/or forms ..... $ Cost	28,000	1,000	53,000	6,400	1,050	33,300	1,000	123,750	
(3) Damage to crops from lack of irrig. or drainage ..... $ Cost	26,500	None	None	18,700	None	3,000	6,300	54,500	
Subtotal ..... $ Cost	160,584	288,600	152,802	47,672	7,950	59,425	8,386	725,419	
b. Ditchbank weeds									
(1) Volume of water lost ..... A.-ft.	19,857	8,922	11,000	13,305	6,868	12,550	3,580	76,082	
Value of water lost ..... $ Cost.	15,927	19,163	35,000	17,036	25,280	14,675	4,716	131,797	
(2) Damage from overflows, seepage, etc. $ Cost	42,000	13,000	23,000	4,400	3,500	4,500	1,000	91,400	
(3) Damage to crops from lack of irrig. or drainage ..... $ Cost	19,500	10,000	None	7,000	2,000	6,100	None	44,600	
Subtotal ..... $ Cost	77,427	42,163	58,000	28,436	30,780	25,275	5,716	267,797	
c. Weeds in flood plains and reservoirs									
(1) Area infested ..... acres	5,010	1,500	1,550	46	2,100	None	None	10,206	
(2) Volume of water lost ..... A.-ft	20,000	6,200	10,500	1,085	5,400	None	None	43,185	
Value of water lost ..... $ Cost	15,000	14,000	49,750	2,235	16,200	None	None	97,185	
(3) Flood damage or other loss ..... $ Cost	2,000	2,100	9,000	1,200	None	100	None	14,400	
Subtotal ..... $ Cost	17,000	16,100	58,750	3,435	16,200	100	None	111,585	
d. Total water losses ($ Cost)	255,011	346,863	269,552	79,543	54,930	84,800	14,102	1,104,801	
(1) Volume of water lost ..... A.-ft	126,388	98,322	64,800	31,860	14,568	31,850	4,340	372,128	
Acre-foot value ..... $ Cost	1.09	3.26	2.85	1.31	3.32	1.19	1.34		2.09
(2) Acre-foot net productive value of water lost ..... $ labor income	15	25	[2]8.33	?	31.33	?	?		
(3) Total net productive value of water lost ..... $ labor income	1,895,820	2,458,050	[2]539,784		453,282				

Table 7 (Continued)

ITEM	BUREAU OF RECLAMATION REGIONS							TOTALS	AVERAGES[1]
	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7		
3. Costs of weed control									
a. Aquatic weeds									
(1) Length of canals treated ..... miles ..	1,544	639	4,570	326.5	2	343.5	24	7,449	
(2) Cost of treatment ..... $ ..	67,718	32,883	199,846	8,312	75	3,807	2,914	315,555	
Average cost per mile ..... $ ..	43.86	51.46	43.73	25.46	37.50	11.08	121.42		42.36
(3) Cost of weed losses prevented .... $ ..	268,500	27,000	418,177	6,902	500	41,250	3,500	765,829	
b. Ditchbank weeds									
(1) Area treated ..... acres ..	18,808	5,553	10,923	2,027.4	9,603	3,934	943	51,791	
(2) Cost of treatment ..... $ ..	117,702	100,214	607,509	62,534	178,991	33,171	11,029	1,111,150	
Average cost per acre ..... $ ..	6.26	18.04	55.62	30.84	18.64	8.43	11.70		21.45
(3) Cost of weed losses prevented .... $ ..	268,000	68,600	1,022,006	7,656	606,864	60,450	600	2,034,176	
c. Weeds in flood plains and reservoirs									
(1) Area treated ..... acres ..	300	10	None	None	1,400	None	None	1,710	
(2) Cost of treatment ..... $ ..	4,500	550	None	None	5,600	None	None	10,650	
Average cost per acre ..... $ ..	15	55	None	None	4	None	None		6.23
(3) Cost of weed losses prevented .... $ ..	10,000	3,000	None	None	None	None	None	13,000	
d. Total costs									
(1) Costs of weed control ..... $ ..	189,920	133,647	807,355	70,846	184,666	36,978	13,943	1,437,355	
(2) Costs of weed losses prevented ... $ ..	546,500	98,600	1,440,283	14,558	607,364	101,700	4,100	2,813,005	
4. Recapitulation									
Total miles of waterways in reported projects ...	5,201	4,425	4,655	1,805	1,957	2,478	880	21,400	
Percent of these that are canals	14.4	30.5	8.2	29.4	16.7	17.6	22.8		18.5
Percent of these that are laterals	66.3	64.5	51.8	52.6	51.2	51.5	52.3		58.0
Percent of these that are drains	19.3	5.0	40.0	18.0	32.1	30.9	24.9		23.5
Total miles of waterways in Region - 1950 Census	27,500	17,230	[3]21,208	21,389	16,209	19,930	20,915	144,381	
Percent of total included in reports	18.9	25.7	21.9	8.3	12.1	12.4	4.2		14.8
Acres of ditchbanks reported for each mile of waterway reported	5.28	2.53	6.50	2.28	2.79	3.23	1.92		4.15
Factor for multiplying totals reported in survey to obtain estimated totals for all waterways and ditchbanks in the region	5.28	3.89	4.54	11.8	8.28	8.04	24.04		6.76

[1] Averages weighted according to total number of miles, acres, or acre-feet in all regions.

[2] Net profit.

[3] Data supplied by C. W. Bowser in letter, 2-5-59.

Table 8.--Extrapolation of data on weed infestations, losses from weeds, and costs of weed control from the reporting districts or companies in each region to all irrigation systems in each region and to all regions in the 17 Western States

ITEM	BUREAU OF RECLAMATION REGIONS							TOTALS
	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	
Extrapolation factor[1]	5.28	3.89	4.54	11.8	8.28	8.04	24.04	
1. General information								
a. Total miles of waterways[2]	27,500	17,230	[3]21,208	21,389	16,209	19,930	20,915	144,381
(1) Canals (miles)	3,955	5,226	1,710	6,265	2,701	3,493	4,784	28,134
Weed infestation:								
(a) Algae miles	1,572	1,625	401	1,180	83	596	231	5,688
(b) Submersed species (pondweeds, etc.) miles	1,201	1,557	841	833	248	699	2,260	7,639
(c) (Omitted)[4]								
(d) Emergent species (cattail, etc.) miles	73	468	133	490	91	92	0	1,347
(2) Laterals (miles)	18,221	11,092	10,958	11,204	8,298	10,261	10,962	80,996
Weed infestation:								
(a) Algae miles	2,580	1,731	775	525	199	1,383	1,442	8,635
(b) Submersed species (pondweeds, etc.) miles	8,468	790	8,224	1,621	638	3,009	4,844	27,594
(c) (Omitted)[4]								
(d) Emergent species (cattail, etc.) miles	472	6,419	200	1,084	95	786	815	9,871
(3) Drains (miles)	5,285	895	8,463	3,828	5,204	6,167	5,409	35,251
Weed infestation:								
(a) Algae miles	1,618	790	554	774	89	1,352	962	6,139
(b) Submersed species (pondweeds, etc.) miles	521	233	3,833	1,322	62	2,330	3,846	12,147
(c) (Omitted)[4]								
(d) Emergent species (cattail, etc.) miles	750	200	1,426	1,782	1,572	2,221	3,757	11,708
b. Total area (acreage) of ditchbanks	145,005	43,630	140,395	48,569	45,225	64,328	40,531	527,683
(1) Area infested with:								
(a) Broadleaved perennials acres	13,649	1,066	5,130	9,959	1,449	6,488	4,495	42,236
(b) Perennial grasses acres	1,426	7,831	44,724	11,658	4,488	161	17,068	87,356
(c) Woody plants acres	1,584	401	66,152	8,449	13,372	6,255	2,741	98,954
(d) Annual weeds acres	68,376	17,944	8,036	16,874	25,999	13,523	15,722	166,474
(e) Total of all weeds acres	85,035	27,242	124,042	46,940	45,308	26,427	40,026	395,020

[1] Extrapolation factor for each region determined by dividing total number of miles of waterways reported for the region in the 1950 Census report by the total number of miles in the projects which reported from that region (Region 3 excepted; see footnote 3 and text footnote 5). These data are reported in table 7.

[2] As reported in the 1950 Census report.

[3] Data supplied by C. W. Bowser in letter, 2-5-59.

[4] Data on floating species not sufficiently important to extrapolate.

Table 8 (Continued)

ITEM	BUREAU OF RECLAMATION REGIONS							TOTALS
	REGION 1	REGION 2	REGION 3	REGION 4	REGION 5	REGION 6	REGION 7	
2. Losses from weeds								
a. Aquatic weeds								
(1) Volume of water lost . . . . . A.-ft. .	456,884	323,648	196,582	206,146	19,044	155,172	18,270	1,375,746
Value of water lost . . . . . $ Cost. .	560,124	1,118,764	453,101	266,349	57,132	185,925	26,107	2,667,502
(2) Damage to canals, structures, and/or farms . . . . . $ Cost. .	147,840	3,890	240,620	75,520	8,694	267,732	24,040	768,336
(3) Damage to crops from lack of irrig. or drainage . . . . . $ Cost. .	139,920	None	None	220,660	None	24,120	151,452	536,152
Subtotal . . . . . $ Cost. .	847,884	1,122,654	693,721	562,529	65,826	477,777	201,599	3,971,990
b. Ditchbank weeds								
(1) Volume of water lost . . . . . A.-ft. .	104,845	34,706	49,940	156,999	56,867	100,902	86,063	590,322
Value of water lost . . . . . $ Cost. .	84,094	74,544	158,900	201,024	209,318	117,987	113,373	959,240
(2) Damage to canals, structures, and/or farms . . . . . $ Cost. .	221,760	50,570	104,420	51,920	28,980	36,180	24,040	517,870
(3) Damage to crops from lack of irrig. or drainage . . . . . $ Cost. .	102,960	38,900	None	82,600	16,560	49,044	None	290,064
Subtotal . . . . . $ Cost. .	408,814	164,014	263,320	335,544	254,858	203,211	137,413	1,767,174
c. Weeds in flood plains and reservoirs[5]								
d. Total losses								
(1) Volume of water lost . . . . . A.-ft. .	561,729	358,354	246,522	363,145	75,911	256,074	104,333	1,966,068
(2) Value of all losses . . . . . $ Cost. .	1,256,698	1,286,668	957,041	898,073	320,684	680,988	339,012	5,739,164
(3) Total net productive value of water lost . . . . . $ labor income . .	10,009,930	9,561,814	2,450,619		3,753,175			
3. Costs of weed control								
a. Aquatic weeds								
(1) Length of canals treated . . . . . miles . .	8,152	2,486	20,748	3,852	16	27,617	577	63,448
(2) Cost of treatment . . . . . $ . .	357,551	127,915	907,301	98,082	621	30,608	70,052	1,592,130
(3) Cost of weed losses prevented . . . . . $ . .	1,417,680	105,030	1,898,524	81,444	4,140	331,650	84,140	3,922,608
b. Ditchbank weeds								
(1) Area treated . . . . . acres . .	99,306	21,601	49,590	23,923	79,513	31,629	22,670	328,232
(2) Cost of treatment . . . . . $ . .	621,466	389,832	2,758,091	737,901	1,482,045	266,695	265,137	6,521,167
(3) Cost of weed losses prevented . . . . . $ . .	1,415,040	266,854	4,639,907	90,341	5,024,834	486,018	14,424	11,937,418
c. Weeds in flood plains and reservoirs[5]								
d. Total costs								
(1) Costs of weed control . . . . . $ . .	979,017	517,747	3,665,392	835,983	1,482,666	297,303	335,189	8,113,297
(2) Costs of weed losses prevented . . . . . $ . .	2,832,720	371,884	6,538,431	171,784	5,028,974	817,668	98,564	15,860,026

[5] Data incomplete in several regions; therefore, they are not included in this extrapolation.